Innovative Testing of Ontario's Asphalt Materials

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Presentation Outline

- Background
- Moisture Sensitivity Tests
- Hamburg Wheel Tracking Test
- Performance Tests using AMPT
- Future Work
  - Performance Tests using DTS-30
  - Bitumen Bond Strength Test (BBS)
- Binder Test Highlights
- Conclusions

Background

- MTO was 100% Superpave mix design by 2005
  - Superpave has mitigated rutting
  - Cracking is still a concern
- Establishing mix performance testing for design and acceptance of placed mix remains a goal
- Work in this area is expected to be ramping up

Stripping by Static Immersion Test

- Determines the stripping susceptibility of the different components of an asphalt mix (MTO LS-285)
- Aggregates are blended with asphalt cement and the blended material is submerged in distilled water at 49°C for 24 hours
- Stripping susceptibility of the asphalt mix is assessed visually based on the percentage of the retained coating on the aggregate

~15% retained coating

~85% retained coating

Stripping by Static Immersion Test

- The percent coating of various samples can be compared to determine what aggregate, AC, and anti-stripping treatment combination, provides better moisture resistance
- Minimum satisfactory value for this test is 65% retained coating

Aggregate Type	No Treatment	Hydrated Lime	Alternative AST-AGG
Granite	15%	85%	90%

Tensile Strength Ratio (TSR)

- Determines the change in tensile strength resulting from moisture conditioning followed by a freeze-thaw cycle of compacted asphalt mixtures (AASHTO T283)
- Test is used during mix design to determine susceptibility of an asphalt mix to moisture damage

- In some cases we find this to be insufficient and specify anti-strip to minimize risk of stripping

Moisture Induced Stress Tester (MIST)

- An alternative moisture conditioning process to the TSR's freeze/thaw conditioning
- In addition to a conditioning process, MIST can be used to evaluate specimens based on sample swelling
- Air voids are measured and the percent swelling is calculated using

$$Swelling = \frac{(BRD_{before} - BRD_{after})}{BRD_{before}}$$

Where:

BRD_{before} = Bulk Relative Density prior to MIST conditioning

BRD_{after} = Bulk Relative Density after MIST conditioning

Moisture Sensitivity Test Results

- The results of liquid anti-stripping treatments (AST-AC) for the moisture sensitivity are:

Aggregate Type	Static Immersion		TSR		MIST -TSR		MIST-Swelling	
	No AST	AST-AC	No AST	AST-AC	No AST	AST-AC	No AST	AST-AC
Granite	15%	90%	67%	98%	62.0%	74.0%	4.2%	3.1%
Diabase	98%	*	84%	98%	69.0%	85.0%	2.0%	1.1%

* Not tested

- The sample with the lowest retained coating, also has the lowest TSR, MIST-TSR and highest swelling value
- Alternately, the diabase had greatest retained coating without AST, the highest TSR, MIST-TSR and lowest swelling
- Testing has resumed using Dolomitic Sandstone aggregate

Hamburg Wheel Tracking Test (HWT)

- MTO uses our Hamburg Wheel Tracking Machine to:
  - Evaluate mixes made with various antistripping additives
  - Evaluate specialty mixes (e.g., fiber reinforced HMA)
  - Investigate premature pavement failure
- Have not used the HWT test to evaluate mixes before they are used in production or to evaluate mix during production

AMPT

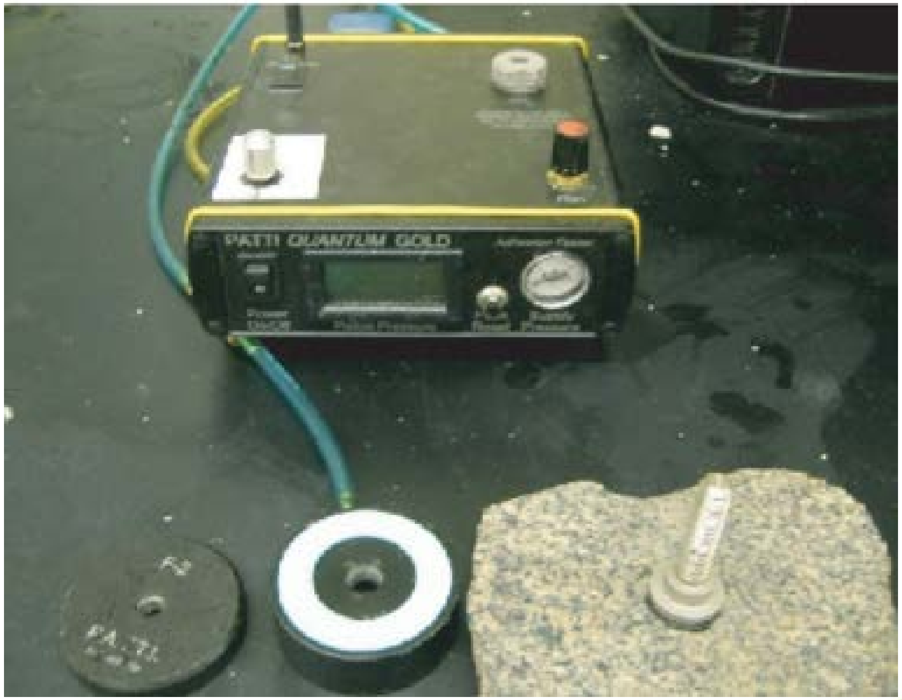
- MTO owns an AMPT (IPC Global) that can run the following tests:
  - Dynamic Modulus
  - Flow Number
  - S-VECD
  - Texas Overlay

Performance Testing using DTS-30

- MTO is purchasing a Dynamic Testing System (DTS-30) that will allow us to run the following:
  - Dynamic Modulus
  - Flow Number
  - Simplified Visco Elastic Continuum Damage (S-VECD)
  - Texas Overlay
  - Four Point Bending
  - **Semicircular Bend (SCB)**
  - **Disk-Shaped Compact Tension (DCT)**
  - **Indirect Tensile (IDT) Creep Compliance and Strength**
  - Resilient Modulus
  - TSRST (Thermal Stress Restrained Specimen Test)

Bitumen Bond Strength Test (BBS)

- The BBS test is a simple procedure to measure moisture resistance of the asphalt-aggregate interface for different combinations of materials
- “*Pull-Off Strength of Coatings Using Portable Adhesion Testers*”. (ASTM D4541)
- Just acquired the device



Future Work

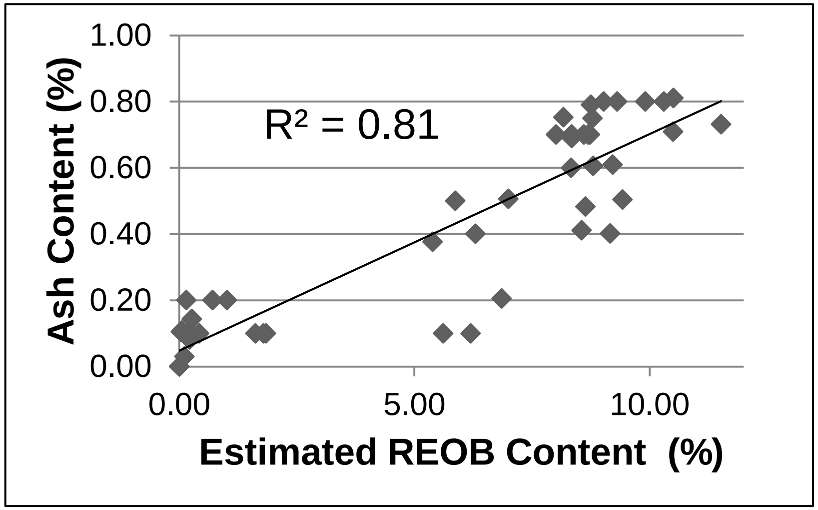
- More testing is planned with MIST and Bitumen Bond Strength Test (BBS)
- MTO is embarking on a large mix testing program (mainly involving SCB, DCT, IDT, HWT)
- Also looking at enhancing our recovery process when evaluating production mix:
  - Currently run RTFO after recovery
  - Solvents used
- MTO will explore testing production mix
- Considering proposals to establish a digital image process that measures the risk of Stripping by Static Immersion

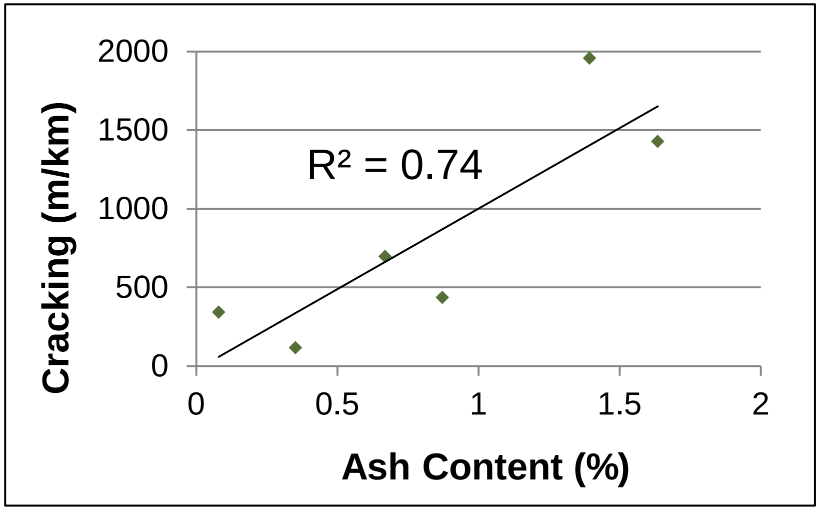
Asphalt Cement Test Innovations

- Ash Content Test
- Extended Bending Beam Rheometer (ExBBR) Test
- X-Ray Fluorescence (XRF)
- Fourier Transform Infrared (FTIR) Spectroscopy

Ash Content Test

- Ash Content test was implemented to prevent over-modification with Re-Refined Engine Oil Bottoms (REOB)
  - Analysis of over 80 samples showed an excellent correlation between ash content and estimated REOB content
  - Limited analysis to date shows excellent correlation between 5 year pavement cracking and ash content





Extended Bending Beam Rheometer (ExBBR) Test

- Determines if AC meets the low temperature performance grade after a physical hardening process that occurs with extended conditioning at cool temperatures
- Test is published as AASHTO TP122-16
- Found best able to predict cracking
- ExBBR determines low temperature grade over 72 hours vs. 1 hour for standard grading

Estimation of 72 Hour Stiffness and Creep

- MTO developed multivariable regression formulae to predict the 72 hour ExBBR test based on 1 and 24 hour properties:

m-value at 72 hrs (T_{ht}) = 0.03239*(m-value @ 1 hr) + 0.88952*(m-value @ 24 hr) + 0.01129

m-value at 72 hrs (T_{lt}) = 0.17770*(m-value @ 1 hr) + 0.795125*(m-value @ 24 hr) -0.00869

S at 72 hrs (T_{ht}) = 0.13495*(S @ 1 hr) + 0.94721*(S @ 24 hr) + 3.34123

S at 72 hrs (T_{lt}) = 0.16874*(S @ 1 hr) + 0.93364*(S @ 24 hr) + 0.14202

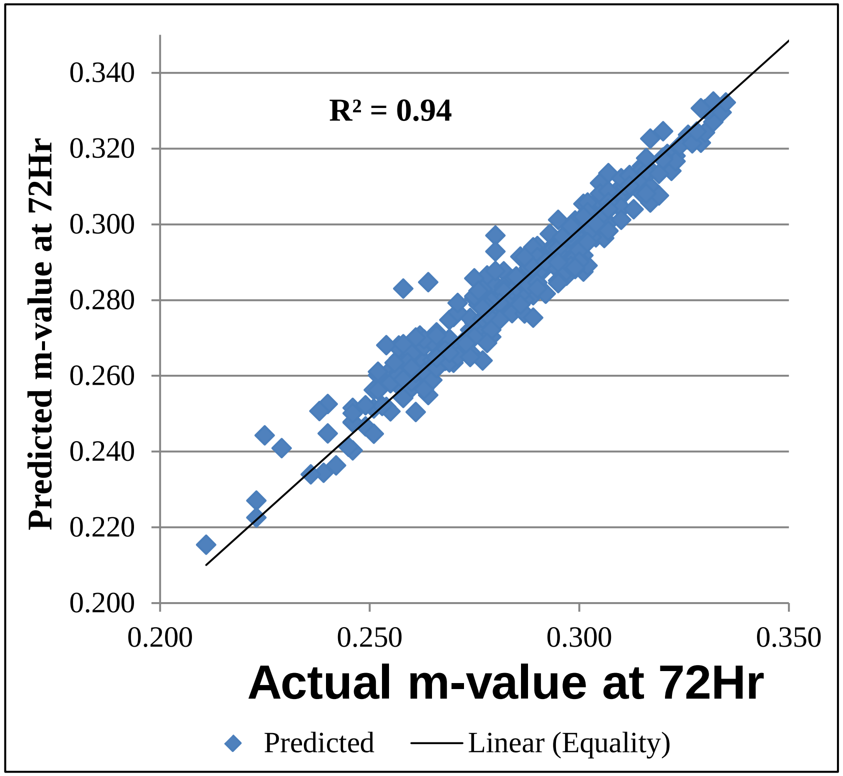
Where:

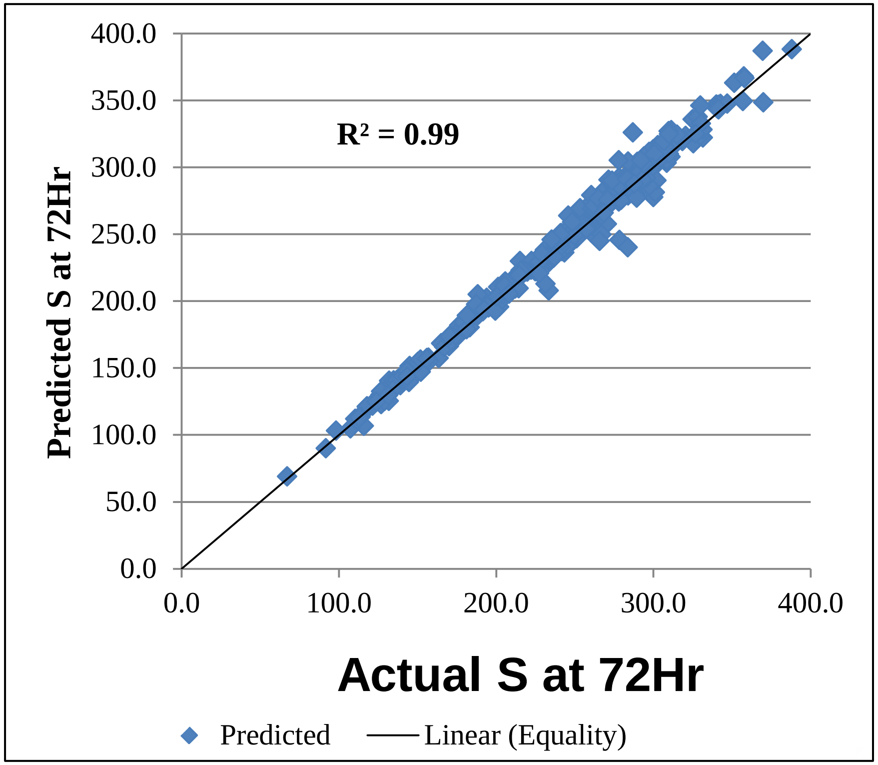
T_{ht} = high test temperature T_{lt} = low test temperature

- Regression analysis was conducted on over 330 ExBBR tests

Estimation of 72 Hour Stiffness and Creep

- The predicted m-value and S can be used to estimate ExBBR Low Temperature Limiting Grade that could be useful for quality control purposes





ΔT_c From BBR/ExBBR Test

- Another useful outcome from the BBR test is the ΔT_c:

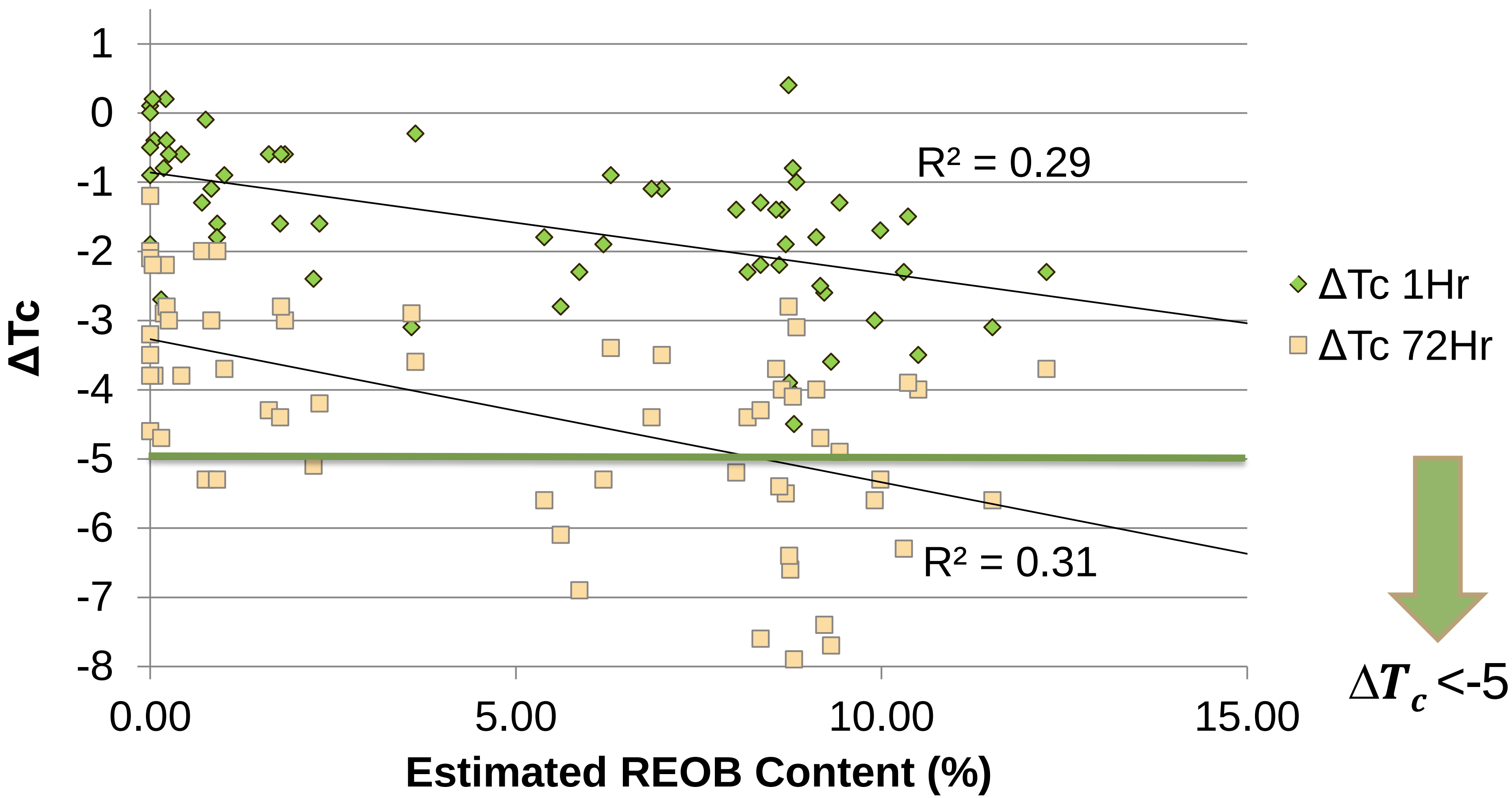
$$\Delta T_c = T_{stiffness} - T_{creep}$$

Where: $T_{stiffness}$ = critical temperature for stiffness (S)

T_{creep} = critical temperature for creep (m-value)

- Of the 62 samples tested, no BBR ΔTc's where <-5, only ExBBR ΔT_c's dropped below -5, while REOB estimates for these samples ranged from 0 to just over 12%
- Recent results:
  - For a PG64-28 was -7.9
  - For recovered AC with and without RAP and RAS, ΔTc ranged from -4.2 to -8.3

Estimated REOB Content vs. ΔT_c



X-Ray Fluorescence (XRF)

- XRF detects the elemental content of a sample
- Transportation agencies, including MTO, are looking at XRF to identify over-modification of REOB in asphalt cement
- Elemental intensity peaks obtained are all relative to other elements found, so calibration curves are required for each element in a material to be quantified (in ppm)
- The four key elements and the levels detected in a REOB sample are:

Calcium	10,000 ppm
Zinc	3,000 ppm
Molybdenum	300 ppm
Copper	100 ppm

X-Ray Fluorescence (XRF)

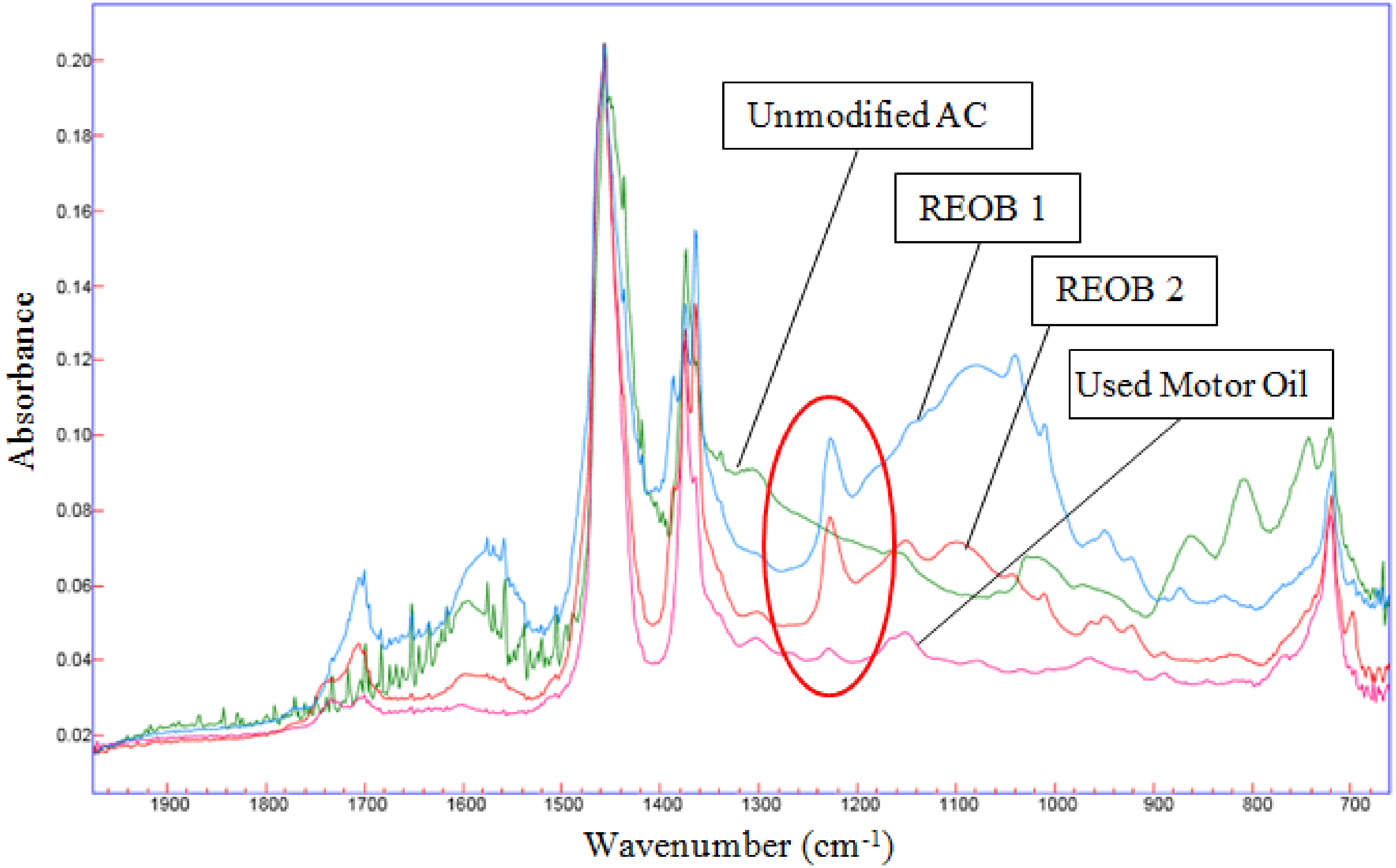
- MTO created calibration curves from base asphalt cement samples with varying percentages of REOB
- A linear regression curve was created for each element
- Equations currently used by MTO for estimating REOB content based on each element follow:

Element	Equation for Estimating REOB Content
Calcium	$REOB\%(Ca) = \frac{XRF(Ca) - 16}{109}$
Zinc	$REOB\%(Zn) = \frac{XRF(Zn) - 14}{48}$
Molybdenum	$REOB\%(Mo) = \frac{XRF(Mo) - 18}{4}$
Copper	$REOB\%(Cu) = \frac{XRF(Cu)}{1.5}$

Fourier Transform Infrared (FTIR) Spectroscopy

- FTIR detects the infrared energy absorbed in a sample
- Comparing FTIR spectra of an unknown sample to a "standard" sample can be used to spot modifications made to an "unknown" sample
- FTIR also provides information on the molecular bond and functional groups of modifications that are made to a material
- We found a unique FTIR absorbance peak corresponding to REOB
- The peak was observed near wavenumber 1229 cm^{-1} - believed to correspond to polyisobutylene, an additive used in engine oil

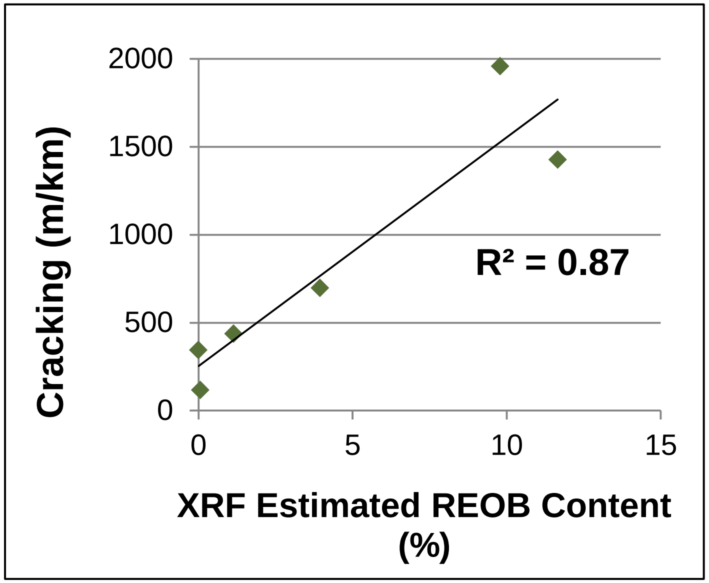
FTIR Spectra



REOB Estimation using FTIR and XRF

- FTIR can identify whether REOB is present in the AC
- MTO is estimating % REOB in AC with XRF
- Results are provided below for:
  - comparison between FTIR peak and XRF estimated REOB content; and
  - five year pavement cracking performance

Sample	FTIR Absorption		XRF Count (ppm)				Average REOB Estimate (%)
	at 1229 cm^{-1}	Peak Present?	Ca	Cu	Zn	Mo	
1	172	**Yes**	937	24	668	79	**13**
2	181	**Yes**	1378	9	331	36	**10**
3	135	**No**	23	0	27	10	**0.1**
4	46	**No**	0	0	11	0	**0**
5	282	**Yes**	945	0	509	29	**5.5**



Conclusions

- Our main focus has been on testing AC, however:
  - MTO has a long history using HWT for investigations and new mixes
  - The use of swelling after MIST conditioning is promising and warrants further investigation
  - Expect to start evaluating various crack predicting mix tests this year
  - Establishing a mix test for cracking, will be Ontario’s first step toward testing production mix for acceptance and will provide Contractors with a tool to use a balanced mix design

Questions?

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